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HUMAN RESOURCES

LABORATORY

AIRBORNE PERFORMANCE MEASUREMENT METHODOLOGY APPLICATION AND VALIDATION:

F-4 POP-UP TRAINING EVALUATION

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A methodology was developed to evaluate pilot performance on the pop-up weapon delivery. Instructor pilot ratings were used to measure performance on the critical stages of the maneuver. Validity of the methodology was assessed using 21 pilots assigned to an F-4 training squadron. Results indicate that instructor pilot ratings of individual stages of the delivery yield a reliable index of the quality of performance on the maneuver. The individual stage performance ratings identified the proficiency levels attained on certain flying skill areas critical to mission readiness. This information enabled an examination of the relationship between pilot learning and training program design.

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PREFACE

This study was conducted by the Flying Training Division of the Air Force Human Resources Laboratory, Air Force Systems Command, in coordination with Headquarters, Tactical Air Command and was supported by the 58th Tactical Fighter Wing and 311th Tactical Fighter Training Squadron at Luke Air Force Base, Arizona. The study supports Project 1123, Flying Training Development; Task 112302, Training Methods and Media. Mr. James F. Smith was project scientist; Dr. Bernell J. Edwards was task scientist; and Dr. Edward E. Eddowes was work unit manager. This reports covers research performed between August and December 1978.

The authors extend their appreciation to the members of the 311th Tactical Fighter Training Squadron for their interest and cooperation throughout this study, and in particular to LtCol Lawrence Day, Maj Morris Norsworthy, and Capt Paul Watson, without whose assistance the work could not have been completed. The authors would also like to thank Mr. Richard Greatorex, Mr. Tien Fu Sun, and 2Lt Mike Williamson of the Flying Training Division for their advice and assistance in analyzing the data.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

AIRBORNE PERFORMANCE MEASUREMENT METHODOLOGY APPLICATION AND VALIDATION: F-4 POP-UP TRAINING EVALUATION

I. INTRODUCTION

Recently the availability of energy and aircraft resources for Air Force flying training has decreased dramatically. As these resources continue to diminish, the demand increases for more effective use of aircraft sorties and training aids. In response to this demand, the Air Force has initiated a flying skills maintenance and reacquisition training research program (Project SMART). The objective of Project SMART is to identify and define the critical combat skills of mission ready aircrews and to develop procedures for measuring these skills. The resulting skill measurement procedures will enable Air Force training managers to increase the efficiency of their programs, to evaluate aircrew maintenance of critical combat skills, and to provide mission ready aircrews at minimum cost. The skill measurement procedures will be used to identify areas of skill deficiency and to assess the effects of modifications in flying training programs. The result of this research effort will be recommendations for improving initial and continuation training programs based on behavioral data and documented flying requirements.

In its current phase, Project SMART has focused on the identification and definition of critical skills required for selected air-to-ground weapon delivery maneuvers and on the development of a methodology to measure these skills. The pop-up weapon delivery maneuver (pop-up) was identified as one of the tasks critical to mission readiness and was chosen for initial study. The pop-up requires a low altitude approach to a pull-up point selected on the basis of its position relative to a target (see Figure 1). At the pull-up point, a specific climb angle is established to achieve enough altitude to acquire the target and set up the bomb run. At the appropriate altitude, the pilot rolls in on the target, apexes, rolls out, establishes the correct dive angle, and flies the aircraft to the release point required for ordnance delivery. Upon ordnance delivery, the pilot takes action to evade ground threats and return to low altitude. (For a more complete discussion on the pop-up delivery and its use in the tactical environment, see Dyches, 1978.) The pop-up is designed to minimize the amount of time spent outside the low altitude environment. By minimizing the time he is exposed to ground threats during weapons delivery, the pilot increases his survivability. Thus, the pop-up is a time-compressed tactical maneuver which requires a variety of heads-up advanced flying skills for its execution.

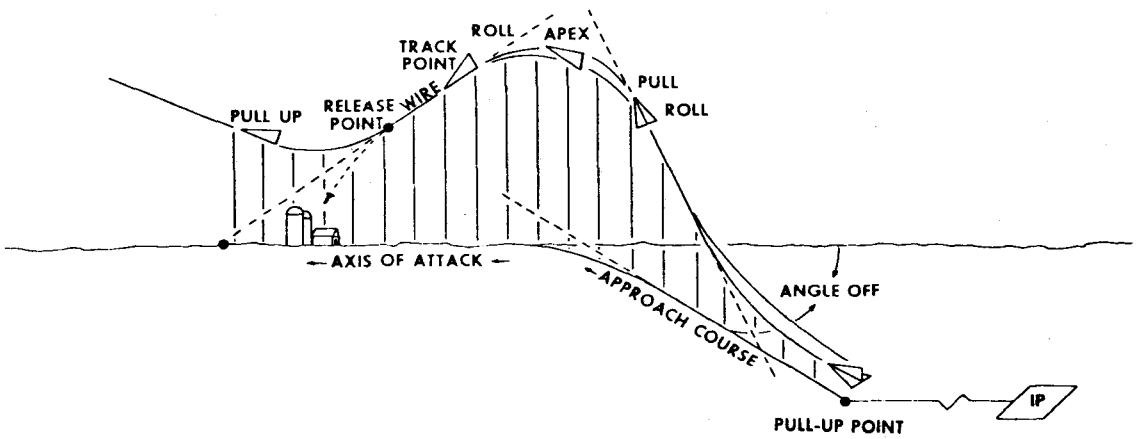

Figure 1. **Pop-up weapon delivery profile.**

At the start of the research, extensive interviews were conducted with mission ready pilots to identify and define the skills critical to pop-up performance. The interview data suggested that pilot planning, cross-check, discrimination, anticipation, decision making, and aircraft control skills were critical to successful performance of the delivery. The more proficient pilot focuses his attention ahead of his aircraft, increasing both his situation awareness and his ability to make rapid error analysis. In developing a methodology for performance measurement, heavy emphasis was placed on procedures to assess cognitive skills through the use of behavioral data.

Published procedures for the pop-up provide precise quantitative specifications of aircraft control parameters. Since means for determining the values of critical aircraft parameters during the pop-up were not available for use in evaluating pilot performance, a performance measurement methodology was developed which took advantage of the pilots' ability to assess performance on the critical stages of the maneuver. A form listing these critical stages in sequence was constructed, on which pilots could rate performance for data collection purposes. Skill levels of the cognitive activities associated with each stage were inferred from the data. This procedure resulted in the identification of basic areas of performance/non-performance.

The present study addresses the validity and applicability of the performance measurement methodology. Pilots in an F-4 combat crew training program served as subjects. This procedure increased the availability of subjects and permitted the use of instructor pilots (IPs) to assess pilot performance.

Objectives

The present study was designed to validate the pop-up performance rating methodology. In addition, the study generated information identifying specific areas of pilot performance/ non-performance.

II. METHOD

Subjects

Twenty-one F-4 B-course pilots assigned to the 311th Tactical Fighter Training Squadron, Luke AFB, served as subjects. All subjects were undergraduate pilot training graduates and had completed fighter lead-in training but had not been qualified in any other operational aircraft. At the time the study was conducted, subjects had just completed the ground attack (GA) and ground attack radar (GAR) phases of the training syllabus. The GA and GAR phases concentrated on training and qualification in basic bombing maneuvers and nuclear deliveries, respectively. The ground attack tactical (GAT) phase followed the GAR phase and introduced the pilot to advanced tactical weapon deliveries including curvilinear and pop-up approaches. Thus, the pop-up performance data obtained in this study were collected on pilots who had not previously performed the pop-up delivery. The GAT-phase concluded B-course training, at which point pilots were considered "mission ready" and assigned to operational units.

GAT Phase Description

The GAT phase consisted of six sorties (GAT-1 through GAT-6) which typically were flown in four-ship formation. In the event of a ground abort, the remaining members of the flight continued the mission in three-ship formation. Sorties GAT-1 through GAT-3 were flown on controlled ranges. Mission planning for these sorties was conducted by the flight IPs. Sortie GAT-1 served as an introduction to curvilinear and pop-up approaches and high angle strage, while sorties GAT-2 and GAT-3 focused on the pop-up and provided the pilot opportunity to become crew-solo qualified. Sorties GAT-4 through GAT-6 were flown on tactical ranges. Sortie GAT-4 introduced

the pilot to planning and flying pop-ups on tactical ranges. On sortie GAT-5, the pilots were required to plan missions simulating a high-threat environment and to brief the procedures of the flight to mission aircrew members. The GAT phase was concluded with sortie GAT-6 in which a mass attack of 12 to 16 aircraft was conducted in coordination with other F-4, F-104, and F-15 squadrons, simulating a high-threat combat environment.

The number of pop-ups performed on each sortie varied, depending on whether the sortie was flown on a controlled or a tactical range. Generally, each pilot performed four to eight pop-ups on controlled range sorties and two to four deliveries on tactical range sorties.

Subjective Rating Form

Pilot performance ratings were collected using the F-4 Pop-Up Evaluation form (see Appendix A). The form segmented the pop-up into nine (controlled range) or ten (tactical range) critical stages. Performance on each stage was rated using a three-point scale (Satisfactory-Marginal-Unsatisfactory). Written explanatory comments were required for all marginal and unsatisfactory ratings.

Bomb scores and estimated bomb release parameters were recorded for each delivery. The best available objective measure of pop-up performance was the circular bomb error or bomb score. Bomb score data were collected for use in validating the subjective ratings obtained on the form.

Procedure

Procedures for data collection were described to all IPs participating in the study at the GAT-phase squadron briefing. Pilot performance was assessed and recorded by IPs at the debriefing of each mission. Stage performance requirements and rating scale descriptions were provided in the instructions on the reverse of each form (see Appendix A). A researcher was available at all times to hand out and collect the data forms and to answer questions. Due to the non-interference nature of this study, manipulation of normal squadron operations was impossible. Therefore, data collection procedures were integrated with normal flight operations throughout the GAT phase. Pop-up performance ratings were collected on all deliveries performed by pilots throughout the phase.

III. RESULTS AND DISCUSSION

Validation of the Performance Measurement Methodology

In order to make inferences about flying skill from the subjective ratings, it was necessary to demonstrate that the ratings are related to the best available objective measure of the quality of a pop-up. In this instance, the validity of the rating methodology was determined by using a composite of the individual stage performance ratings to predict bomb score.

In constructing the composite performance rating score, it was assumed that performance on each stage of the pop-up is relatively independent of performance on the preceding stage when that stage is performed with little error. However, gross error during a stage greatly impairs performance of subsequent stages. For example, consider stages 4 and 5, target acquisition and pull-down point, respectively. As long as the target is acquired in a timely manner, pull down could be executed even if the target acquisition stage was executed poorly. However, if the target was not successfully acquired, or was acquired after a long delay, performance on the pull-down stage would be impaired by the need to correct for errors in the earlier stage. Thus, for purposes of scoring, it was assumed that a rating of unsatisfactory on any stage of the delivery precluded satisfactory execution of subsequent stages, and scoring of the delivery was terminated at that stage. A rating of marginal was assumed to reflect performance which was adequate to permit

satisfactory execution of the next stage of the delivery but was below the criterion of acceptable performance. It was given a value of zero and scoring continued through subsequent stages. A rating of satisfactory was assumed to reflect acceptable performance and was given a value of one. The total composite score was obtained by adding the value of the rating for each stage in sequence until a stage was rated unsatisfactory or the delivery was completed. Thus the range of scores was zero (approach to pull-up point (PUP) rated unsatisfactory) to nine on the controlled range or ten on the tactical range (all stages rated satisfactory).

Consider for example the two pop-ups shown in Figure 2. The scoring of delivery *A* would proceed as follows:

Stage	Rating	Score	Total Score
1. APP to PUP	SAT	1	1
2. PUP	SAT	1	2
3. CLIMB LEG	MAR	0	2
4. TGT ACQ	SAT	1	3
5. PULL DOWN	UNSAT	STOP	3

Delivery:	A	B
Task Evaluation		
1. Approach to PUP	S	S
2. PUP	S	S
3. Climb Leg	M	S
4. Target Acquisition	S	M
5. Pull Down Point	U	S
6. Apex	S	S
7. Track Point	S	M
8. Bomb Run	S	M
9. Recovery	S	S
10. Rtn to Low Alt	S	S

Figure 2. **Composite scoring method – example.**

In scoring delivery *B*, which had no unsatisfactory stages, one point would be assigned for each rating of SAT (Satisfactory), thus giving a total score of 7. Therefore, even though delivery

A had a greater number of satisfactory ratings than delivery *B*, it received a lower score due to the unsatisfactory rating early in the delivery. Bomb scores were grouped into seven categories: (a) less than 50 feet, (b) 50 to 99 feet, (c) 100 to 149 feet, (d) 150 to 199 feet, (e) 200 to 299 feet, (f) unscorable (300+ feet), and (g) aborted pass (no bomb release for reasons of safety).

The relation between composite performance rating and bomb score is shown in Figure 3. It can be seen that more accurate bombs are given higher subjective composite task ratings. The mean rating for bombs in the 0 to 49-foot category was 8.2, while the mean rating for aborted passes was only 3. The magnitude of the relationship was assessed with a chi-square contingency coefficient (Siegel, 1956). Bomb score error and composite rating score were found to be strongly related (contingency coefficient = .664, $P < .001$). This result shows that subjective pilot ratings of individual stages of the pop-up yield a reliable indicator of the quality of performance on that delivery. An additional characteristic of the scoring scheme is that it assumes errors made early in the delivery are more critical than are errors made late in the delivery. The composite scoring system weights early errors more heavily by omitting more stages from scoring following an earlier unsatisfactory rating than following a later such rating. The strong relation between composite score and bomb score suggests that this shift in emphasis over the course of the delivery is a reflection of the actual criticality of errors within each stage. More will be said about this point in the discussion of the data on the individual stages of the delivery.

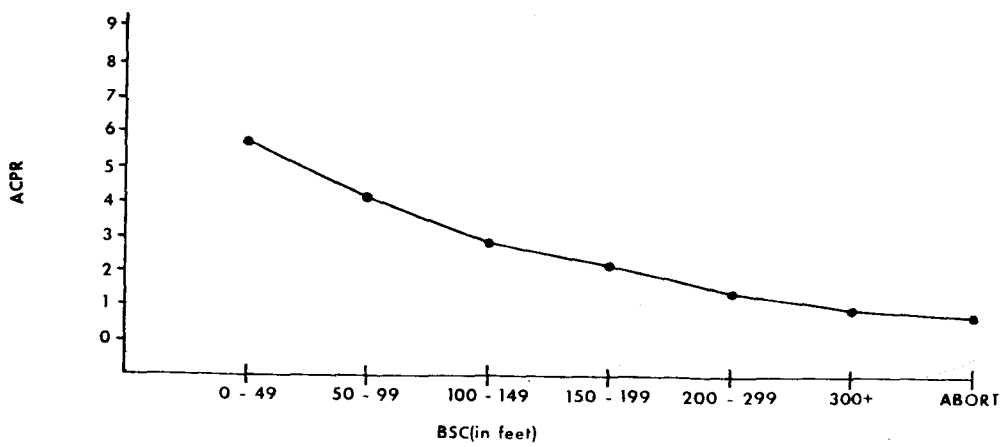

Figure 3. **Methodology validation results.**

Stage-by-Stage Analysis of the Pop-Up

Rating of individual stages of the pop-up provides detailed information for error analysis which is not available from overall objective measures, such as bomb score. It provides information about which stages of the delivery are more difficult, which improve most over training, and how this improvement affects the entire delivery.

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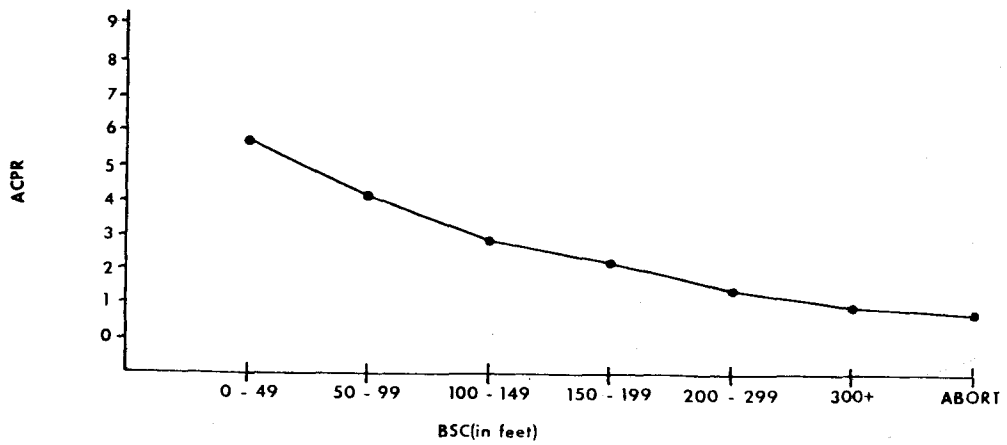

AVERAGE COMPOSITE PERFORMANCE RATING (ACPR)

X

BOMB SCORE CATEGORIES (BSC)

CONTINGENCY COEFFICIENT = .664

P < .001

Figure 3. **Methodology validation results.**

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low altitude flight and BFM receive little emphasis prior to this training phase. The performance on Stage 7, track point, and Stage 8, bomb run, reflects the level of proficiency attained by pilots during the GA phase.

In the more difficult stages, the same differential effect of training is evident. Stages 1, 2, and 5 show substantial improvement, although performance on these stages does not reach the level attained on stages 3 and 4. On the other hand, performance on stages 6, 7, and 8 shows little improvement over the course of the 15 passes. In general then, it is the initial stages of the pop-up delivery which improve during the controlled range phase of training, and this improvement occurs regardless of the initial difficulty of the stage. The effect of the improvement in performance of the initial stages is reflected both in bombing accuracy and in the subjective ratings. The median bomb score decreased from about 160 feet to 143 feet, and the average composite score increased from 5.4 to 6.8. This improvement results because the pilot's improved performance on the initial stages (prior to apex) places him in a better position to start his dive. Thus, errors in later stages of the delivery have a reduced effect on overall performance, even though performance on these stages has improved only slightly. The difference in the criticality of the stages to success of the pass is a result of the cumulative effect of error in the sequence. An error made early in the pass, perhaps more than a mile from the release point, can result in a large displacement from the desired position by the time the release point is reached. An error of the same magnitude made late in the delivery, on the other hand, is less critical because the weapon is released before the error condition can attain as serious a magnitude. Thus, early errors have a greater effect on overall performance and can require more extreme corrective action than errors made in later stages.

Tactical Range Performance. The performance on the tactical range (see Table 3) was similar to that on Sortie GAT 3 (controlled range). The initial performance on all task stages was slightly lower compared to performance on later control range passes, but the relative difficulty of the stages was similar. The exception was target acquisition which was markedly lower compared even to early control range performance. This depression reflects the greater difficulty of acquiring poorly defined targets on the tactical range. By the end of the GAT phase, the pilots attained considerable skill at all stages of the delivery, although performance has not reached a 100% satisfactory level.

Table 3. **Stage-by-Stage Analysis of the Pop-Up – Tactical Range Performance**

			Task Breakdown: Percent Satisfactory										Bomb Scores		
GAT	PASS	TOT PLT	1 APP TO PUP	2 PUP	3 CLIMB LEG	4 TGT ACO	5 PULL DOWN	6 APEX	7 TRK PNT	8 BMB RUN	9 REC	10 RTN TO LO LVL	MED BOMB SCORE	N	MEAN COMP RATING
4	1	21	76	81	86	67	86	86	71	57	76	57	32	12	6.14
	2	17	88	88	88	59	76	76	71	47	88	59	50	11	6.13
5	1	21	95	62	86	90	81	67	71	62	90	71	100	14	7.06
	2	14	86	71	93	93	79	86	64	36	79	64	125	8	5.75
6	1	21	90	81	95	95	76	81	86	71	90	90	32	14	7.81

IV. CONCLUSIONS

The pop-up rating methodology was successfully used to evaluate pilot performance on the pop-up. The results of the present study demonstrated the validity of the performance rating methodology. Several important conclusions can be drawn from the present results:

1. Subjective ratings of pilot performance can provide a valid and reliable measure of pilot proficiency. This was shown by the high contingency coefficient obtained between the composite rating score and bomb score. This composite rating score was obtained from 3-point (Satisfactory-Marginal-Unsatisfactory) ratings of nine/ten critical stages of the maneuver.

2. Ratings of the individual stages of the delivery provide information that is not available from overall objective performance measures, such as bomb score. Stage ratings provide information about skill areas which give pilots initial difficulty and about the effect of training and practice on proficiency at skills required for combat readiness.

3. The stage analysis permits inferences to be made about the effectiveness of training programs. In the present study, performance on individual stages of the pop-up reflected the amount of emphasis given to certain flying skill areas up to this point in the F-4 training program. These areas are low altitude awareness/aircraft handling (stages 1 and 2), instrument crosscheck (stage 3), basic fighter maneuvers (stages 5 and 6), and basic bombing (stages 7 and 8). In some skill areas, pilots in the present study showed considerable mastery. In other skill areas, pilots' level of proficiency was lower.

Low Altitude Awareness/Aircraft Handling

During the approach to PUP, and PUP, the pilot must navigate and maneuver the aircraft under severe time pressure. This time stress is compounded by the stress of flying in the very unforgiving low-altitude environment. Prior to this phase of training, pilots have not performed high-g, low altitude maneuvering or target area navigation. As a result, performance on the initial stages of the pop-up is poor, and these stages are not fully mastered by the end of the GAT phase.

Instrument Cross-Check

The climb leg is basically an instrument task, involving setting a climb angle and heading. This skill has been practiced frequently since the start of F-4 transition training. Pilots have little difficulty in mastering it in the GAT phase.

Basic Fighter Maneuvers (BFM)

Skill at BFM, that is, the capacity to maneuver the aircraft by feel, is exercised primarily in the medium- to high-altitude combat environment. As the F-4 has been phased out of the air-to-air role, emphasis on BFM in the syllabus has been reduced. The apex and pull-down stages both draw heavily on BFM skills. These stages are performed poorly and are not completely mastered during the GAT phase.

Basic Bombing

The basic bombing skill is initially acquired during the GA phase, which precedes the GAT phase. At the start of the GAT phase, it is the skill area which gives pilots the greatest difficulty, and at the end of the phase, it remains the most difficult. In fact, the track-point and bomb-run stages show the least improvement of any during the GAT phase. This is not too surprising, since the pilot has his hands full with many new and difficult tasks prior to reaching the basic bombing stages of the pop-up. The interviews with pilots and the rating data suggest that basic bombing skills are more effectively acquired when they are practiced in relative isolation (e.g.,

during the GA phase). Thus, improving performance on the track point and bomb run stages could best be accomplished by increasing the basic bombing training given in the GA phase.

B-Course Syllabus

The Tactical Air Command has recently modified the B-course training syllabus in an effort unrelated to the present research. These changes have involved adding low altitude awareness training (LAAT) prior to the GAT phase, increasing the amount of basic bombing in the GA phase, and decreasing the amount of BFM. These changes can be expected to impact pilot performance in learning the pop-up during the GAT phase. The addition of LAAT may result in greater pilot proficiency on approach to PUP and pull-up. Increasing basic bombing may lead to improved performance on the track point and bomb run stages of the pop-up, and the decreased emphasis on BFM might be expected to lead to poorer performance on pull-down and apex. A study is planned to address these questions when pilots in the modified B-course reach GAT phase.

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Siegel, S. *Nonparametric statistics for the behavioral sciences.* New York: McGraw-Hill, 1956.

APPENDIX A: DATA COLLECTION MATERIALS

F-4 GAT PHASE EVALUATION

PILOT #:_____ IP #:_____ RANGE #:_____

EVENT:_____ RIDE #:_____ DATE:_____

Release Parameters	PASS # 1st	2nd	3rd	4th
Estimated Dive Angle	___	___	___	___
Estimated Altitude (AGL)	___	___	___	___
Estimated Airspeed	___	___	___	___
Bomb Score	___	___	___	___

TASK EVALUATION					COMMENTS/INDICATE PASS #
1. Approach to PUP	___	___	___	___	_____
2. PUP	___	___	___	___	_____
3. Climb Leg	___	___	___	___	_____
4. Target Acquisition	___	___	___	___	_____
5. Pull Down Point	___	___	___	___	_____
6. Apex	___	___	___	___	_____
7. Track Point	___	___	___	___	_____
8. Bomb Run	___	___	___	___	_____
9. Recovery	___	___	___	___	_____
10. Return to Low Level	___	___	___	___	_____

Legend: S - Satisfactory M - Marginal U - Unsatisfactory

The pop-up evaluation form was developed to assess student pilot performance on pop-up weapon deliveries. Additionally, this form can be used as a briefing and debriefing aid. Tape recorders will be provided to assist the crew in gathering data pertinent to completion of the form.

INSTRUCTIONS

1. COMPLETE THE PILOT IDENTIFICATION PORTION OF THE FORM

2. RECORD ESTIMATED RELEASE PARAMETERS AND BOMB SCORES.

3. GRADE THE TASK EVALUATION SECTION AS FOLLOWS:

   S - Satisfactory. Task performance met criteria with minimal error; minimal compensations were required.

   M - Marginal. Task performance met criteria with error; compensations were required to salvage the pass delivery.

   U - Unsatisfactory. Task performance did not meet criteria; gross errors in performance led to either an unsafe or aborted pass.

Any item graded as either M or U requires an appropriate explanation under the comments section. The following indicates those requirements identified with each item included in the Task Evaluation section:

1. Approach to PUP: (a) Acquisition of PUP; (b) Altitude control; and (c) Airspeed control.

2. PUP: (a) Heading correction; (b) "G" application; (c) Airspeed correction.

3. Climb Leg: (a) Climb angle corrections.

4. Target Acquisition: Self-explanatory

5. Pull Down Point: (a) Roll; (b) Airspeed corrections; and (c) "G" application.

6. Apex: (a) Pattern correction; and (b) Airspeed corrections.

7. Track Point: (a) Aim off point; (b) Roll out; (c) Initial wind correction; and (d) Angle check.

8. Bomb Run: (a) Aiming error corrections; (b) Airspeed control; and (c) Exposure time control.

9. Recovery: (a) "G" application; and (b) Jinking.

10. Return to Low Level: (a) Exposure time; and (b) Transition to low level.

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